Evaluation of GISS Regional Model (RM3) Weather Forecasts Over West Africa During the 2014 Summer Monsoon

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ABSTRACT

The West African Monsoon (WAM) is a seasonal climate system that affects the Sahel region of West Africa. The WAM supplies most of the annual accumulation of precipitation to the Sahel during June - September, nourishing farmland. Agriculture is the main source of income for Sahel's population. Because of the socio-economic impacts of Sahel rainfall, predicting that rainfall is important. The African Center of Meteorological Applications for Development (ACMAD), based in Niamey, Niger, uses the Regional Model 3 (RM3), a regional climate model developed at the NASA Goddard Institute for Space Studies (GISS), to issue daily precipitation forecasts for the Sahel. However, daily weather forecasts produced by the RM3 require more extensive evaluation. In this project, precipitation forecasts made by the model during the region's 2014 rainy season are evaluated by comparing the model's forecasts to observations from 52 weather stations in the region, and to forecasts made by the National Center for Environmental Prediction's (NCEP's) Global Forecast System (GFS) weather model. The performance of various historical precipitation datasets (derived from station observations, satellites, and other observations), such as the Climate Prediction Center Merged Analysis of Precipitation (CMAP), Global Precipitation Climatology Project (GPCP), and Tropical Rainfall Measurement Mission (TRMM), are also compared over West Africa, to assess the value of using each of these datasets as a baseline for evaluating model performance. The study finds that the GFS is more skillful in predicting precipitation over West Africa during June-September 2014. While the GFS produces too many moderate forecasts, the RM3 produces too many heavy forecasts, especially just north of the Gulf of Guinea. The RM3 also under predicts rainfall over the Sahel, between 13N and 16N. The study also finds that differences between the CMAP and GPCP precipitation datasets, as represented by their 1998-2010 means, are small, relative to their differences with TRMM.

MAP OF AFRICAN STATIONS

ANALYSIS AND METHODS

Various measures of error are computed using each model forecast F_i and station observation O_i, and then compared.

$$(F_i; i = 1,2,...,n) \qquad (O_i; i = 1,2,...,n) \qquad (e_i =; i = 1,2,...,n)$$

$$e_i = F_i - O_i \qquad n = number\ of\ iterations$$

Root Mean Square

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n} e_i^{\,2}}$$

Mean Absolute Error

$$MAE = \frac{1}{n}\sum_{i=1}^{n} |e_i|$$

Mean Error

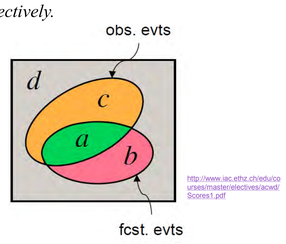
$$ME = \frac{1}{n}\sum_{i=1}^{n} e_i = \overline{F} - \overline{O}$$

Where $\overline{F}$ and $\overline{O}$ are the model-predicted and observed means, respectively.

Threat Score

$$TS = \frac{a}{a+b+c}$$

Where a represents the correct observed and forecasted events, c represents the observed events, and b represents the forecasted events.



http://www.iac.ethz.ch/edu/courses/master/electives/acwd/Scores1.pdf

Biased Score

$$BS = \frac{a+b}{a+c}$$

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National Aeronautics and Space Administration (NASA)
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RESULTS

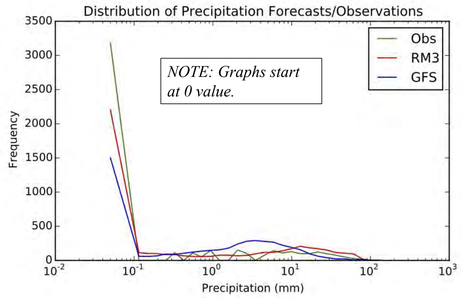

Figure 1: Distribution of Precipitation Forecasts and Observations

- GFS simulates more instances of moderate rainfall, while RM3 simulates more instances of heavy rainfall.
- Neither simulates enough days with no rainfall.

ERROR MEASURE RESULTS

Score	Value [0.254]	[2.54]	[6.50]	[12.7]	[25.4]
r	0.19				
RMSE	14.31				
MAE	6.45				
ME	2.11				
TS	0.39	0.25	0.20	0.14	0.08
BS	1.35	1.50	1.64	1.70	1.73

Score	Value [0.254]	[2.54]	[6.50]	[12.7]	[25.4]
r	0.27				
RMSE	10.59				
MAE	4.23				
ME	-0.40				
TS	0.42	0.31	0.23	0.14	0.08
BS	1.84	1.60	1.03	0.59	0.38

Table #1&2: Various seasonal error measures for RM3 and GFS, respectively.

Ideal Values
r = 1
RMSE = 0
MAE = 0
ME = 0
TS = 1
BS = 1

Highlighted indicates that the measure is statistically significantly larger than its counterpart at the 95% confidence level.

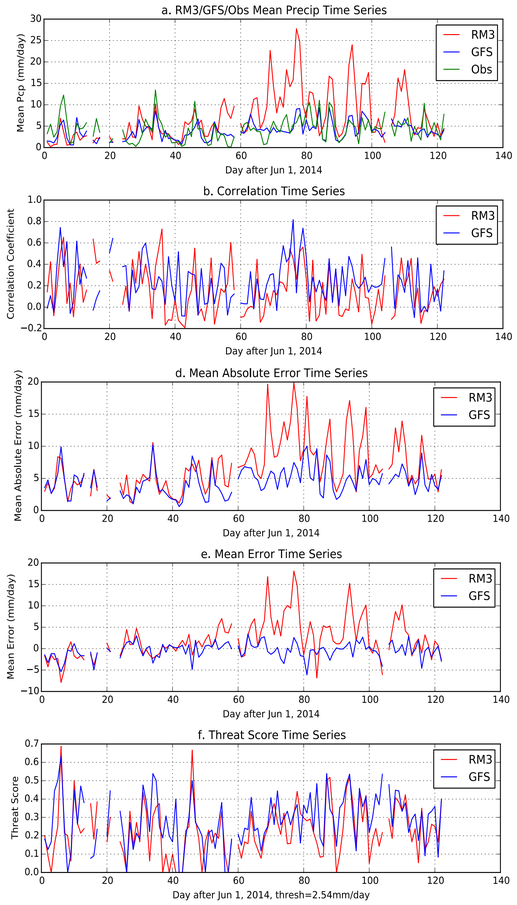

Figure 2: Time series of various error measure for GFS and RM3.

1. Consistency between GFS, RM3, and observations before mid July.
2. Large increase in RM3 simulated regional average precipitation and errors after mid July.
3. Fluctuations in RM3 and GFS mean rainfall and error measures are fairly consistent.

SPATIAL DISTRIBUTION OF RELATIVE ERRORS

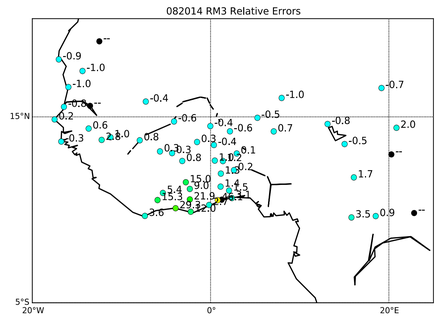

Figure 3: Spatial Distribution of RM3 Relative Errors (Forecast – Observed)/ Observed

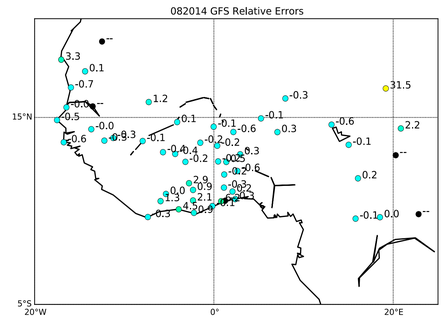

Figure 4: Spatial Distribution of GFS Relative Errors (Forecast – Observed)/ Observed

PRECIPITATION DATASET COMPARISON

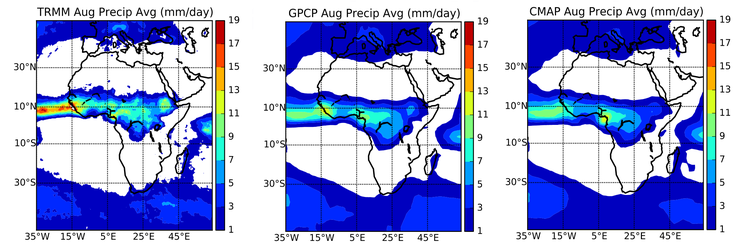

Figure 5, 6, and 7: August precipitation averages from TRMM, GPCP, and CMAP, respectively.

CORRELATIONS	GPCP	CMAP	TRMM
GPCP	1.00	0.98	0.83
CMAP		1.00	0.80
TRMM			1.00

Mean Error	GPCP (2)	CMAP (2)	TRMM (2)
GPCP (1)	0.00	0.13	0.17
CMAP (1)		0.00	0.04
TRMM (1)			0.00

RMS Errors	GPCP	CMAP	TRMM
GPCP	0.00	0.47	1.39
CMAP		0.00	1.48
TRMM			0.00

Table 3, 4, and 5: Correlation, Mean Error ((1)-(2)), and RMS Errors in comparing precipitation datasets.

CONCLUSIONS

1. Error measures show that the GFS performs consistently better than RM3 during June-September 2014.
2. GFS simulates moderate rainfall events too frequently.
3. RM3 simulates heavy rainfall events too frequently.
4. Both GFS and RM3 under predict the number of occurrences of no rainfall.
5. RM3 simulations, GFS simulations, and observations are fairly consistent through mid July.
6. RM3 begins to simulate far too much rainfall after mid July.
7. RM3 simulates far too little rainfall over almost the entire region during June 2014.
8. RM3 simulates too much rainfall along northern coast of the Gulf of Guinea, from July-September 2014.
9. RM3 simulates too little rainfall over the Sahel, near 13-16N.
10. RM3 has an overall positive precipitation bias.
11. GFS consistently simulates slightly too little rainfall over the region during June-September 2014, but has averages that are much closer to the observed averages than the RM3. Overall: negative precipitation bias.
12. The rain band is narrower and heavier for TRMM than for CMAP and GPCP.
13. GPCP and CMAP are very similar, except that CMAP indicates more precipitation near Cameroon, while GPCP indicates more precipitation near Sierra Leone.

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